Demonstration of principle of CRFQ

present status and foreseen

Daniele Davino

davino@unisannio.it

Department of Engineering

University of Sannio, Benevento, Italy

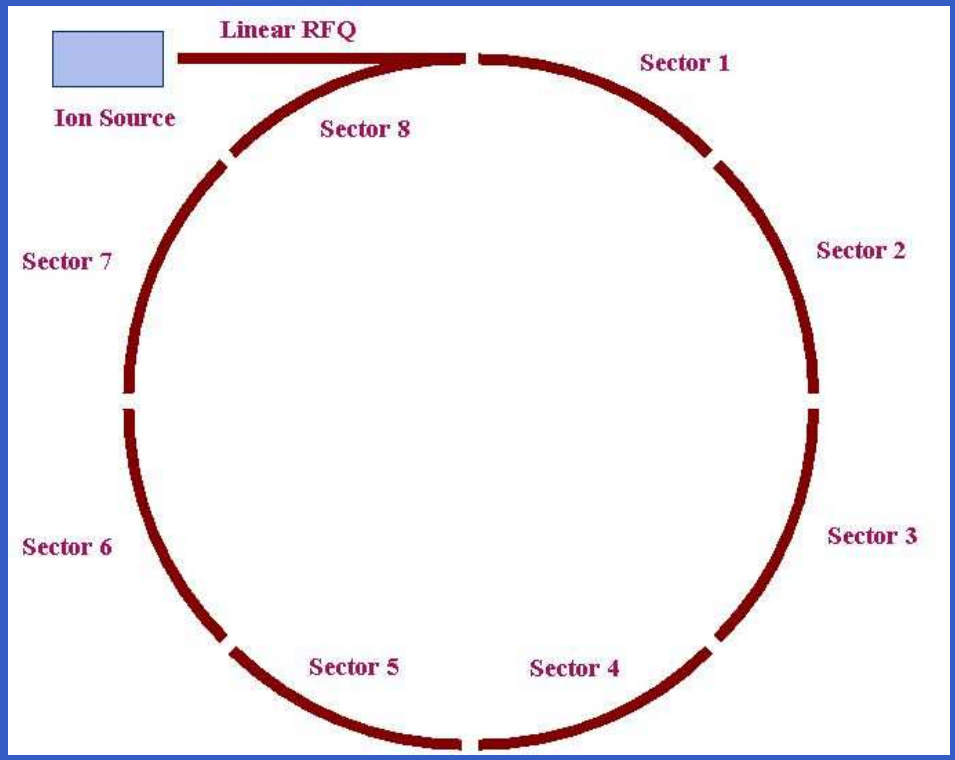
Outline

- Introduction
- Status of RF (linear module)
- RF power measurements
- Status of proton source
- Time schedule and foreseen

CRFQ Collaboration team

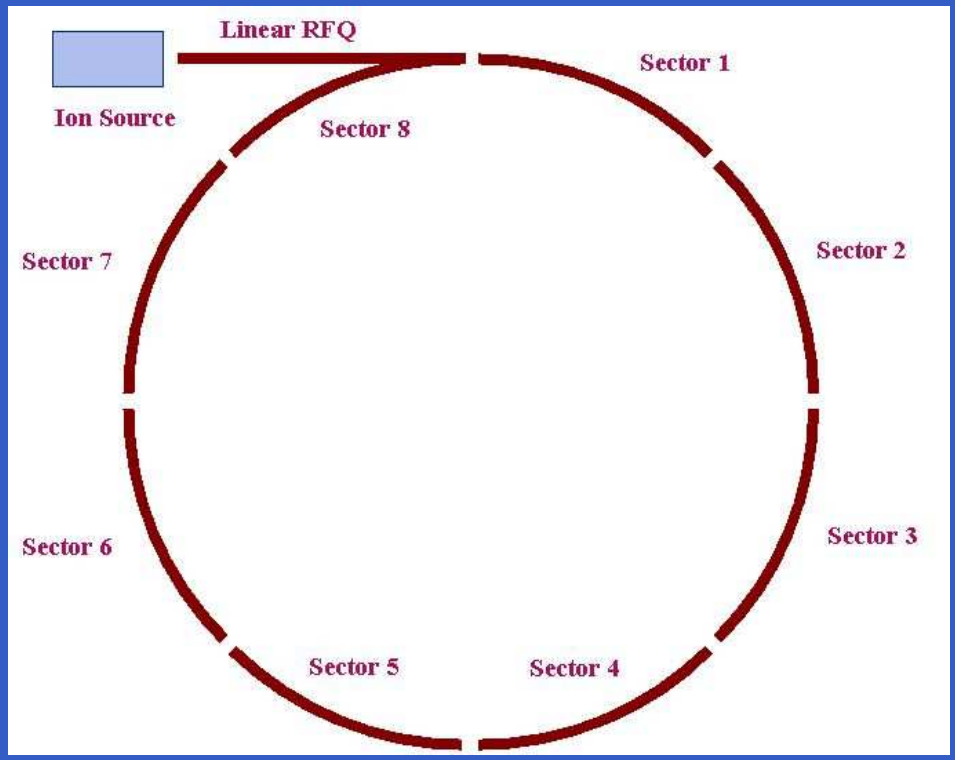
- Daniele Davino, University of Sannio
- Luigi Campajola, Vittorio G. Vaccaro, Physics dept., University of Napoli
- Maria Rosaria Masullo, INFN
- Alessandro G. Ruggiero, V. Lo Destro, Joe Tuozzolo, and others, Brookhaven National Laboratory
- **Advisors**: Maurizio Vretenar (CERN), Augusto Lombardi (LNL, Italy).

The CRFQ



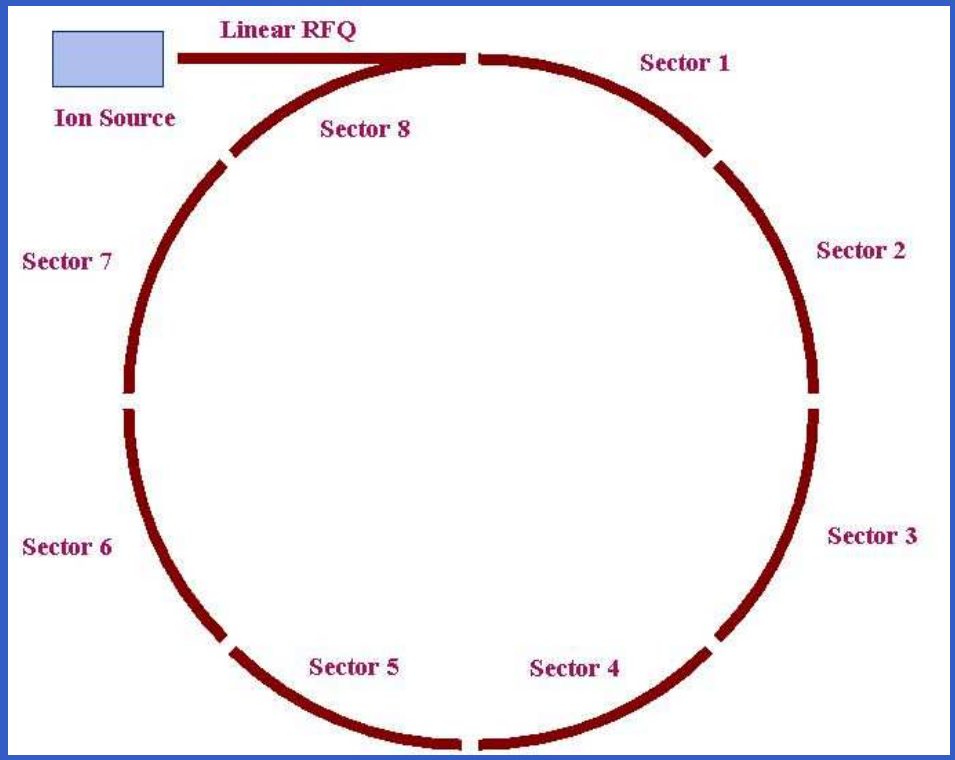
- RadioFrequency quadrupole completely bent on a circle

The CRFQ



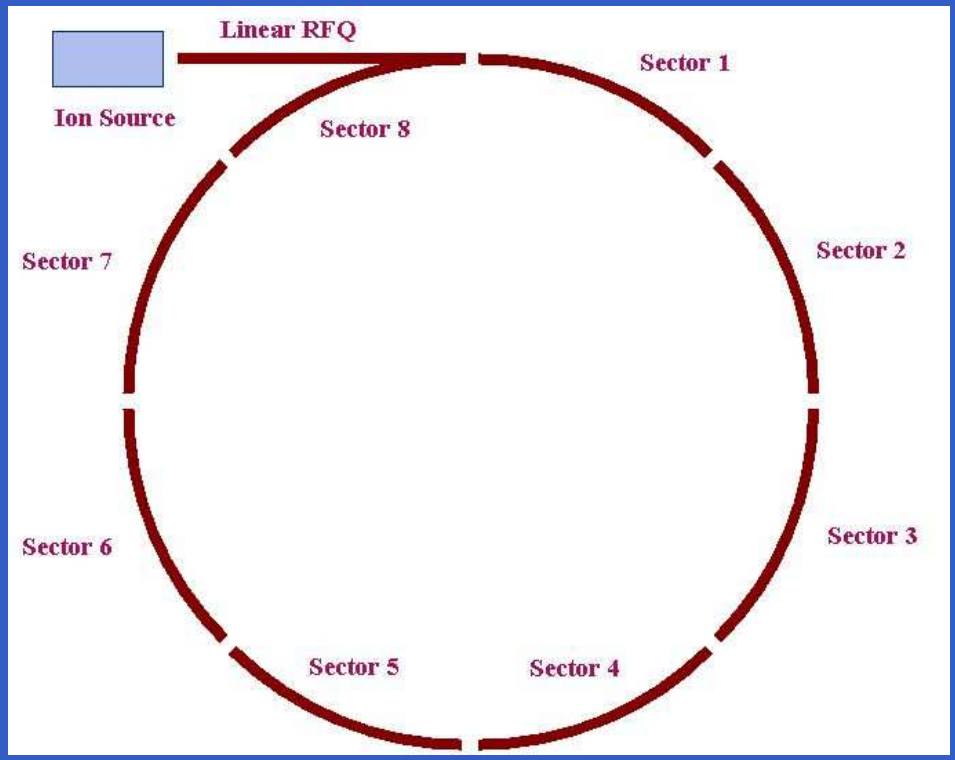
- RadioFrequency quadrupole completely bent on a circle
- higher beam intensity, smaller beam dimensions

The CRFQ



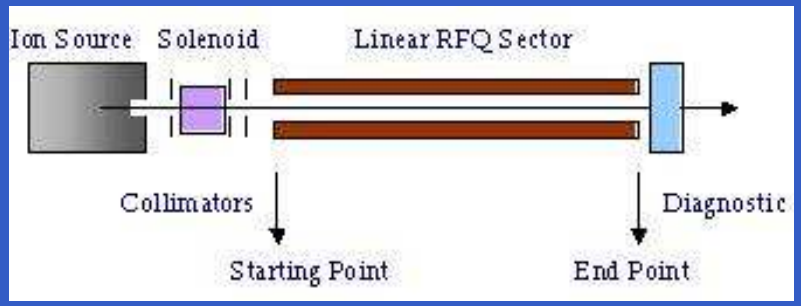
- RadioFrequency quadrupole completely bent on a circle
- higher beam intensity, smaller beam dimensions
- open issues: injection, extraction, acceleration

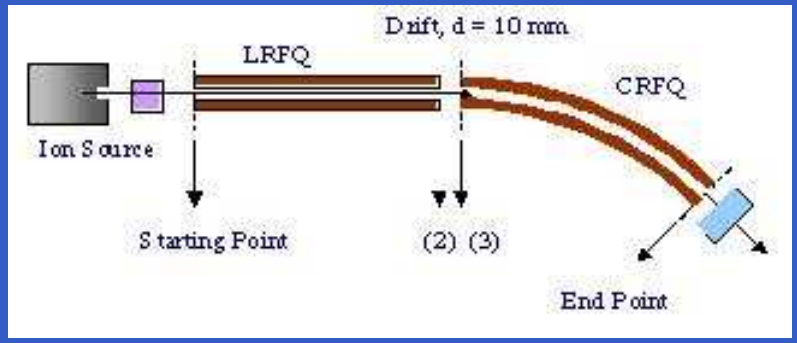
The CRFQ



- RadioFrequency quadrupole completely bent on a circle
- higher beam intensity, smaller beam dimensions
- open issues: injection, extraction, acceleration
- proof of principle!

Aim of the collaboration





- Development of a 30keV, 1mA proton beam source
- Linear sector (first phase – RF check & beam Matching)
- Linear + 45° curved sector(s) (second phase – bending principle)

Beam Parameters

Rods radius	5mm
Gap radius	5mm
Electrodes length	700mm
Input energy	30keV
Beam current	1mA
Transverse emittance	10π mm mrad
Longitudinal voltage distribution	$\pm 5\%$
Max. dipole error	$\pm 2\%$

RF Parameters

- RF power amplifier

f [MHz]	202.56
Power	20 kW
Duty cycle	0.2%
Peak Voltage	36 kV
Field flatness	bt $\pm$5%
Rsh	73 kΩm min

RF Parameters

- RF power amplifier $\Rightarrow$ RF frequency and duty cycle,

f [MHz]	202.56
Power	20 kW
Duty cycle	0.2%
Peak Voltage	36 kV
Field flatness	bt $\pm$5%
Rsh	73 kΩm min

RF Parameters

- RF power amplifier $\Rightarrow$ RF frequency and duty cycle,
- average dissipated power of 100W

f [MHz]	202.56
Power	20 kW
Duty cycle	0.2%
Peak Voltage	36 kV
Field flatness	bt $\pm$5%
Rsh	73 kΩm min

RF Parameters

- RF power amplifier $\Rightarrow$ RF frequency and duty cycle,
- average dissipated power of 100W $\Rightarrow$ no water cooling

f [MHz]	202.56
Power	20 kW
Duty cycle	0.2%
Peak Voltage	36 kV
Field flatness	bt $\pm$5%
Rsh	73 kΩm min

RF Parameters

- RF power amplifier $\Rightarrow$ RF frequency and duty cycle,
- average dissipated power of 100W $\Rightarrow$ no water cooling
- particle beam dynamic $\Rightarrow$ peak voltage, field flatness,

f [MHz]	202.56
Power	20 kW
Duty cycle	0.2%
Peak Voltage	36 kV
Field flatness	bt $\pm$5%
Rsh	73 kΩm min

RF Parameters

- RF power amplifier $\Rightarrow$ RF frequency and duty cycle,
- average dissipated power of 100W $\Rightarrow$ no water cooling
- particle beam dynamic $\Rightarrow$ peak voltage, field flatness,
- dissipated peak power: $\Rightarrow$ shunt impedance minimum

f [MHz]	202.56
Power	20 kW
Duty cycle	0.2%
Peak Voltage	36 kV
Field flatness	bt $\pm$5%
Rsh	73 kΩm min

Status of RF

- Setup of the RF Power Source (CERN, 50kW, 202.56MHz)
- Linear hot model built and working
- Power tests performed
- Bead-pulling performed

Status of RF

- Setup of the RF Power Source (CERN, 50kW, 202.56MHz)
- 48kW deliverable to a dummy load
- Linear hot model built and working
- Power tests performed
- Bead-pulling performed

Status of RF

- Setup of the RF Power Source (CERN, 50kW, 202.56MHz)
- 48kW deliverable to a dummy load
- Linear hot model built and working
- 700mm long, 150 diameter steel outer cyilinder, 10mm diameter copper rods, 6 copper stems.
- Power tests performed
- Bead-pulling performed

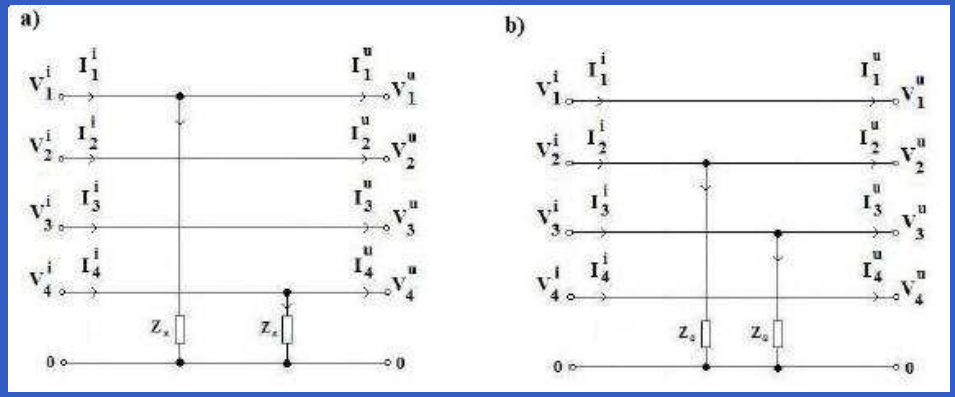
Status of RF

- Setup of the RF Power Source (CERN, 50kW, 202.56MHz)
- 48kW deliverable to a dummy load
- Linear hot model built and working
- 700mm long, 150 diameter steel outer cyilinder, 10mm diameter copper rods, 6 copper stems.
- Power tests performed
- 32kW deliverable to the LRFQ
- Bead-pulling performed

Cold model measurements

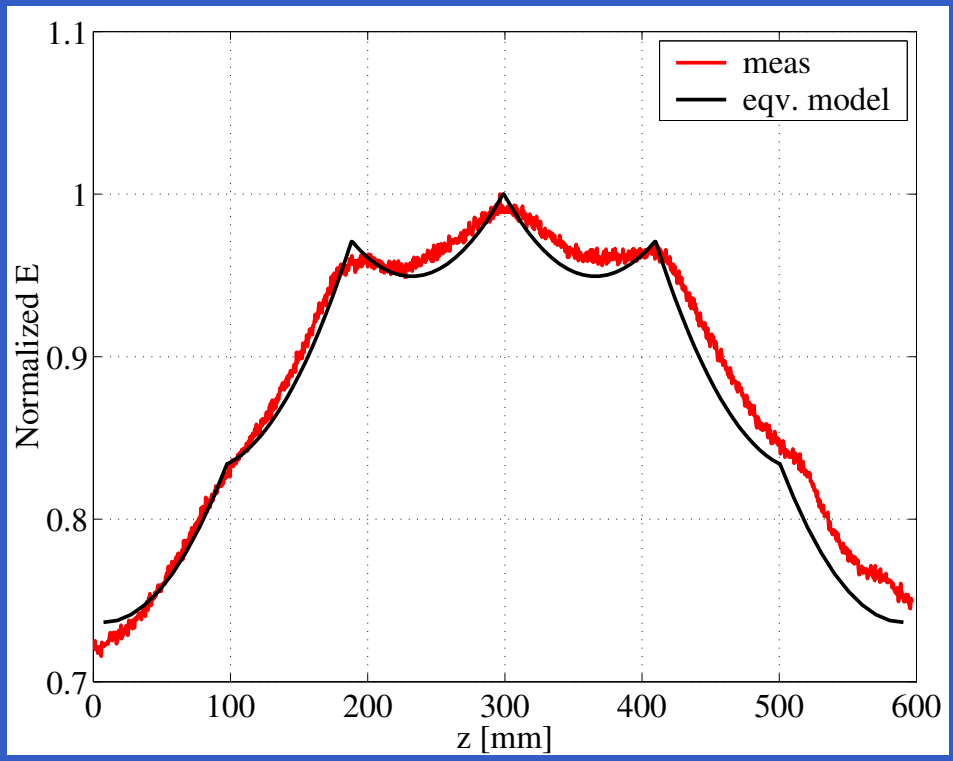
- cold model (5 stems) $\Rightarrow$ checks RF solutions

Cold model measurements



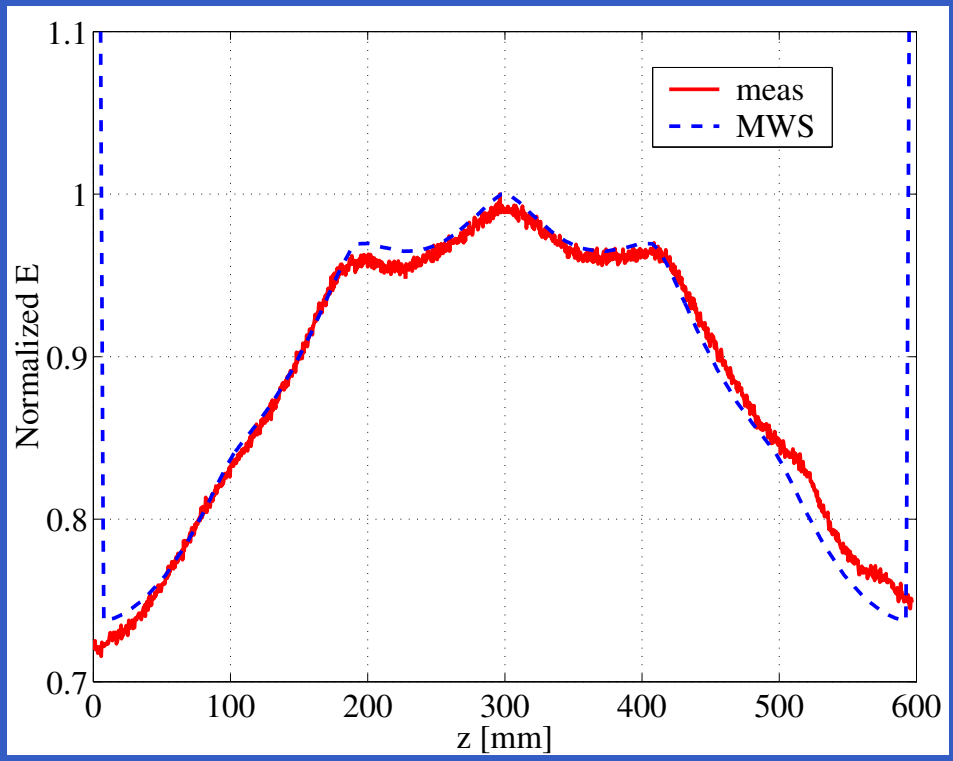
- cold model (5 stems) $\Rightarrow$ checks RF solutions
- equivalent model based on periodically loaded transmission lines

Cold model measurements



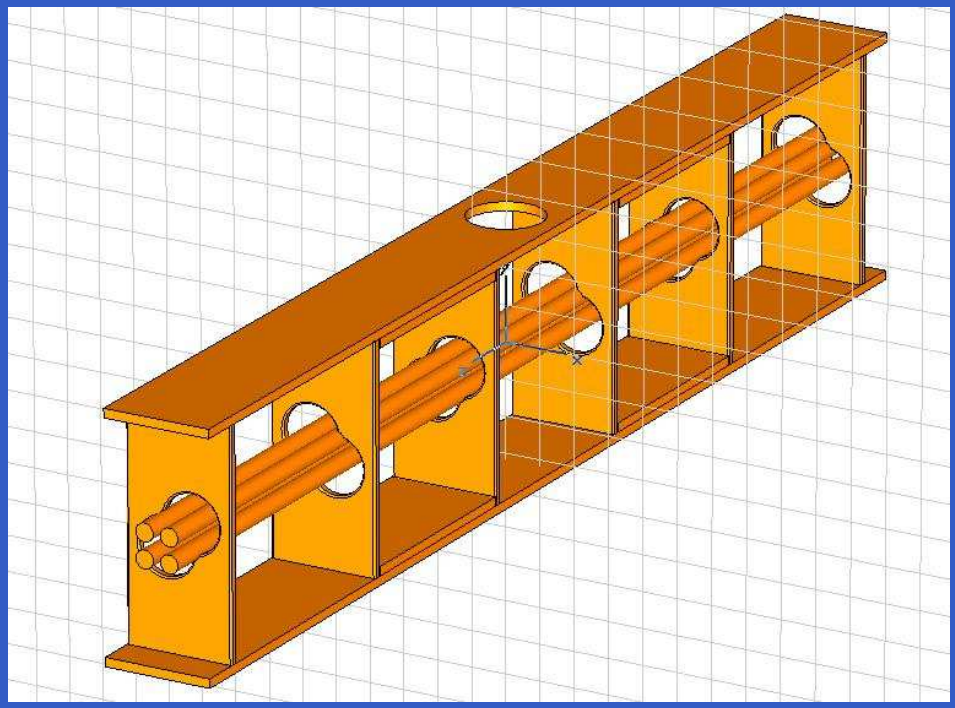
- cold model (5 stems) $\Rightarrow$ checks RF solutions
- equivalent model based on periodically loaded transmission lines
- good agreement with bead pulling

Cold model measurements



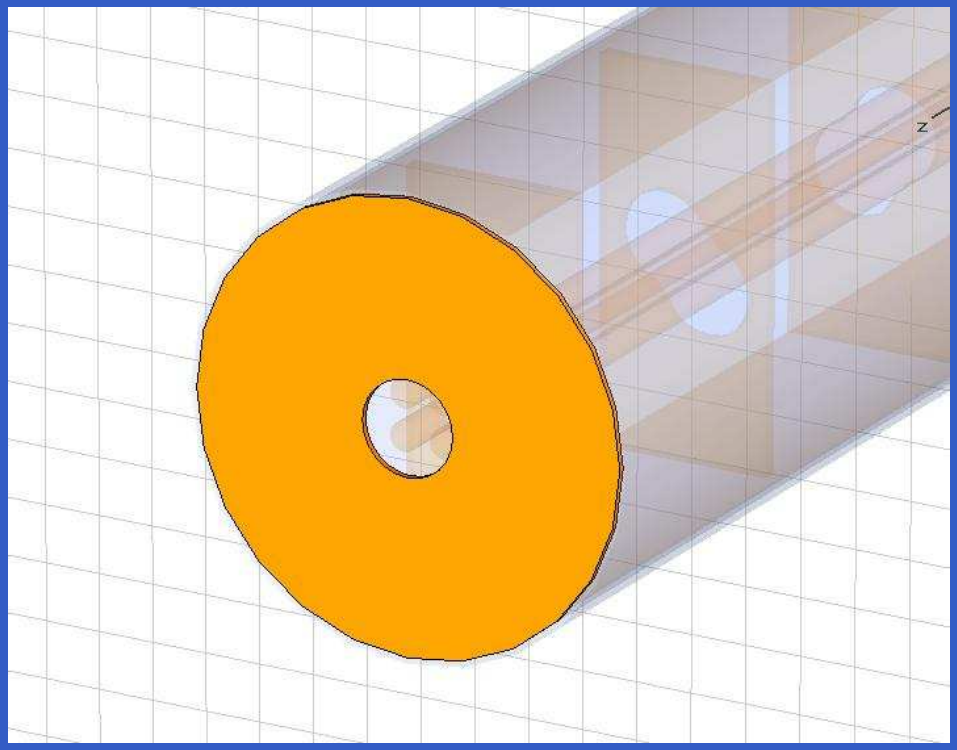
- cold model (5 stems) $\Rightarrow$ checks RF solutions
- equivalent model based on periodically loaded transmission lines
- good agreement with bead pulling
- numerical simulations (CST microwave studio)

Hot model design



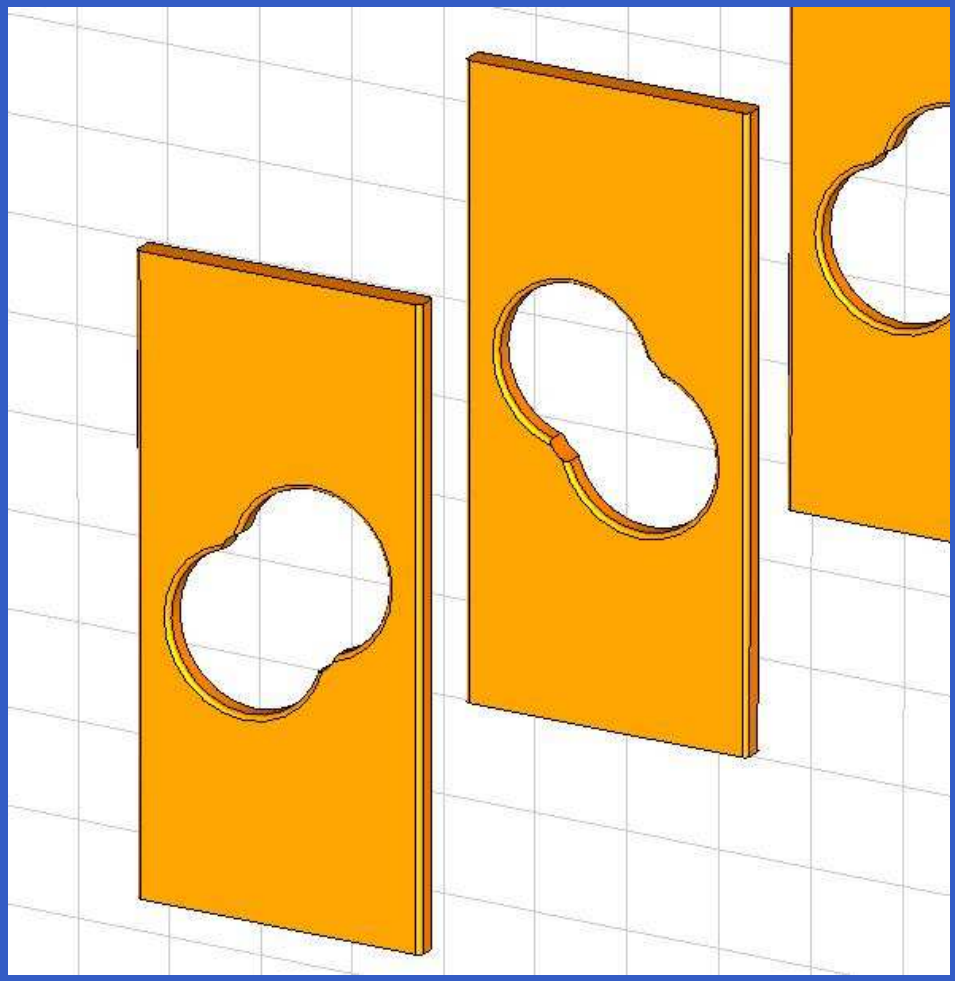
- Six stems, center hole for power loop

Hot model design



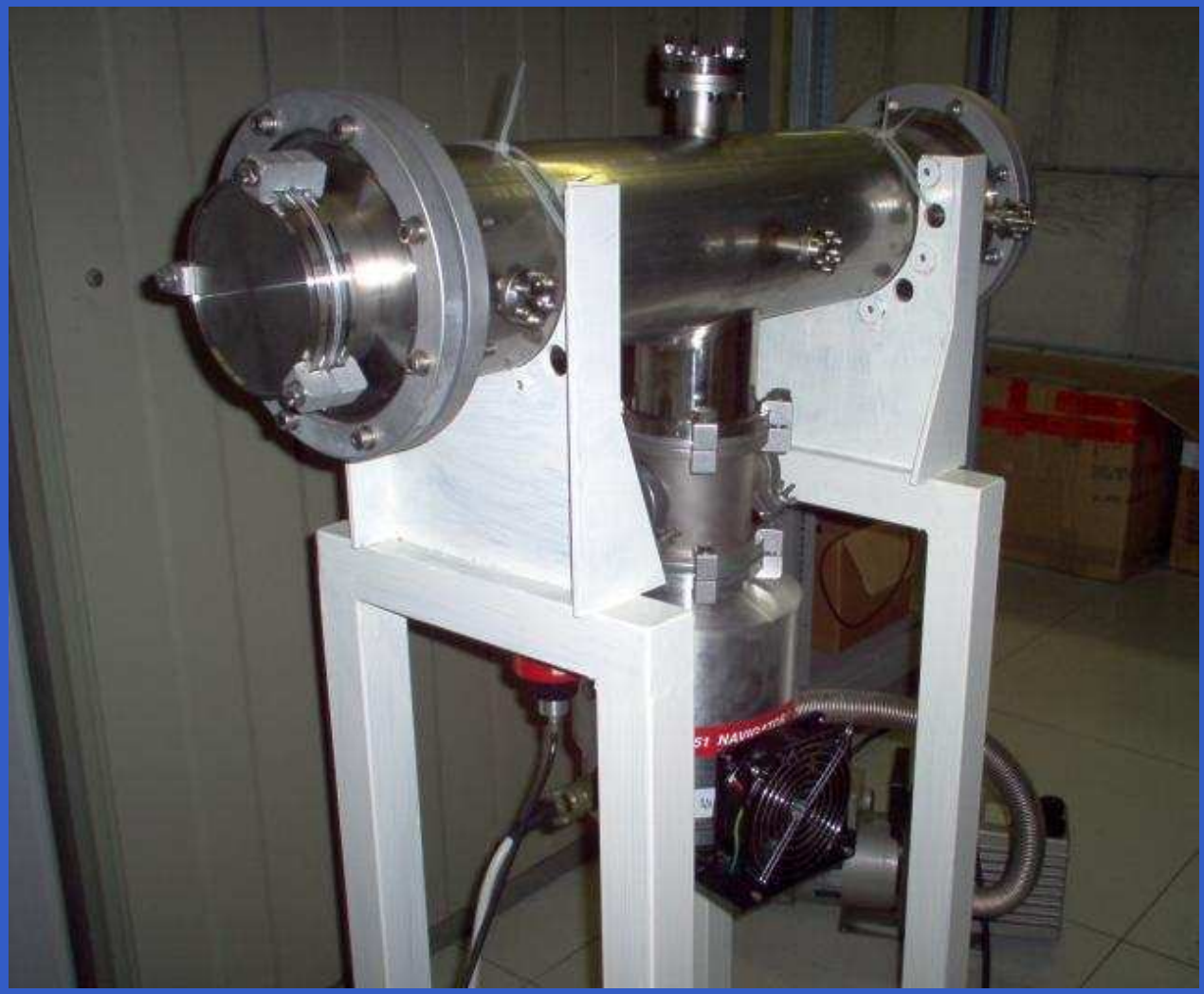
- Six stems, center hole for power loop
- end disks for tuning and e.m. shielding

Hot model design

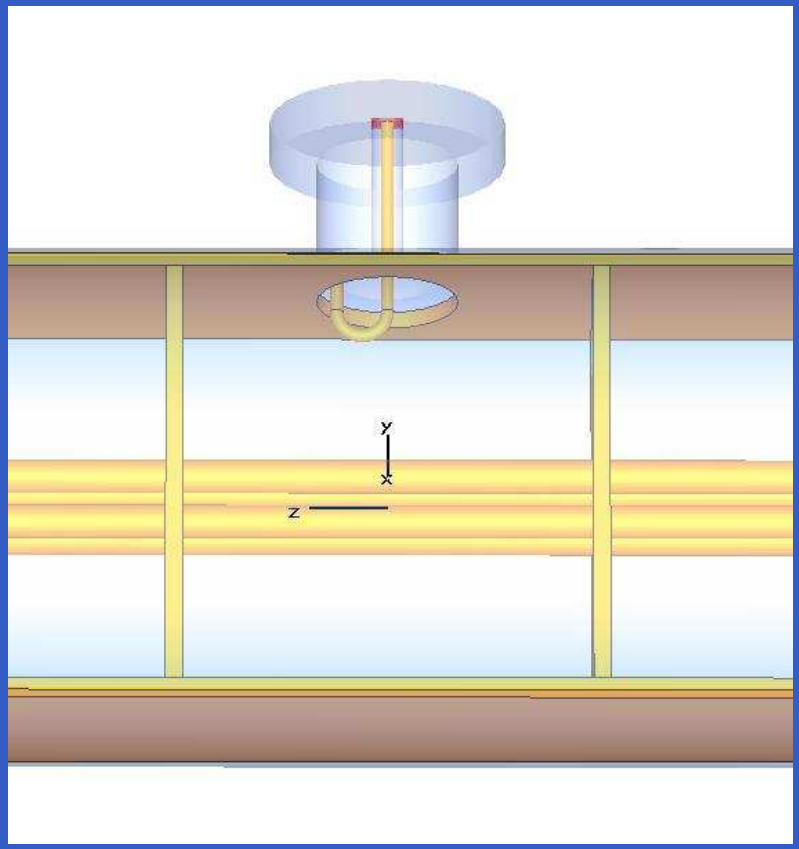


- Six stems, center hole for power loop
- end disks for tuning and e.m. shielding
- easy machining tiles, shimming of corners

Hot model



Power loop design

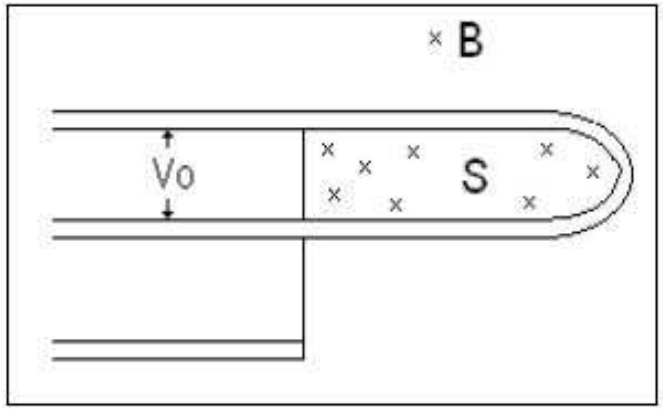


Power loop design

$$V_0 = 2\pi f B S$$

$$P = \frac{1}{2}\frac{V_0^2}{Z_0}$$

$$\frac{\sqrt{2PZ_0}}{2\pi f} = BS$$

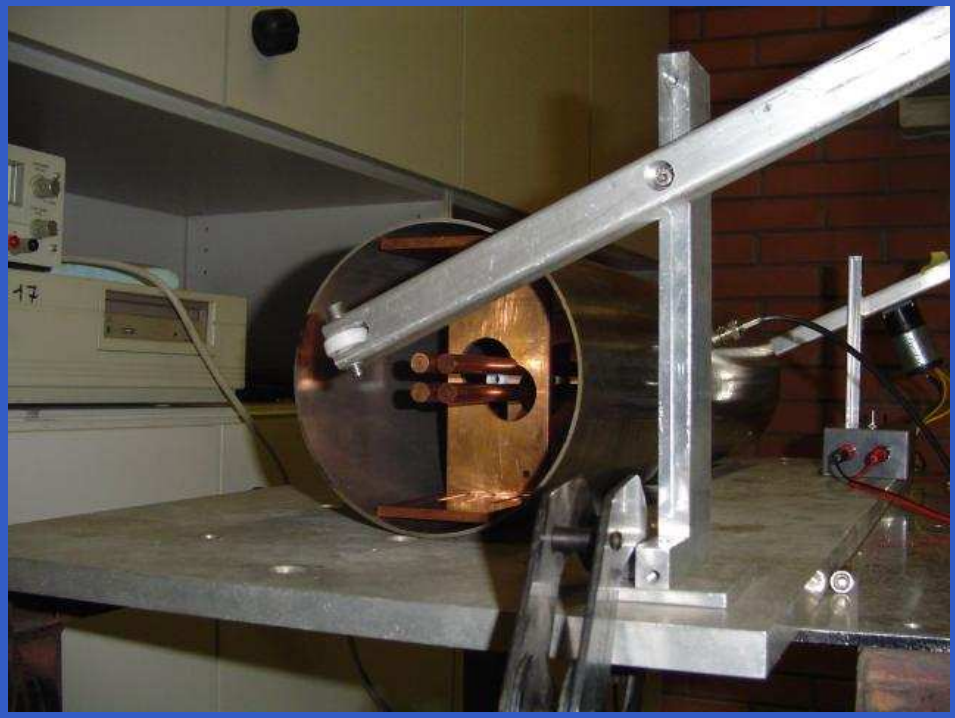


$$\frac{P_{MW}}{B_{MW}^2} = \frac{20KW}{B^2}$$

$S \sim 2{,}3\ cm^2$

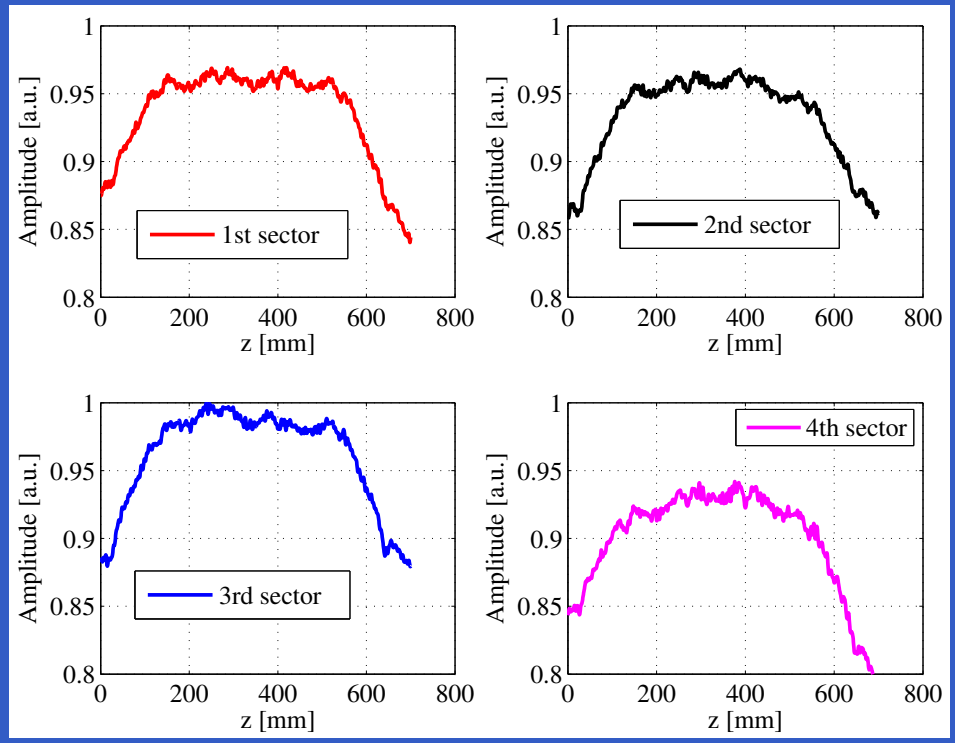
Power loop design

Bead pulling (hot model)



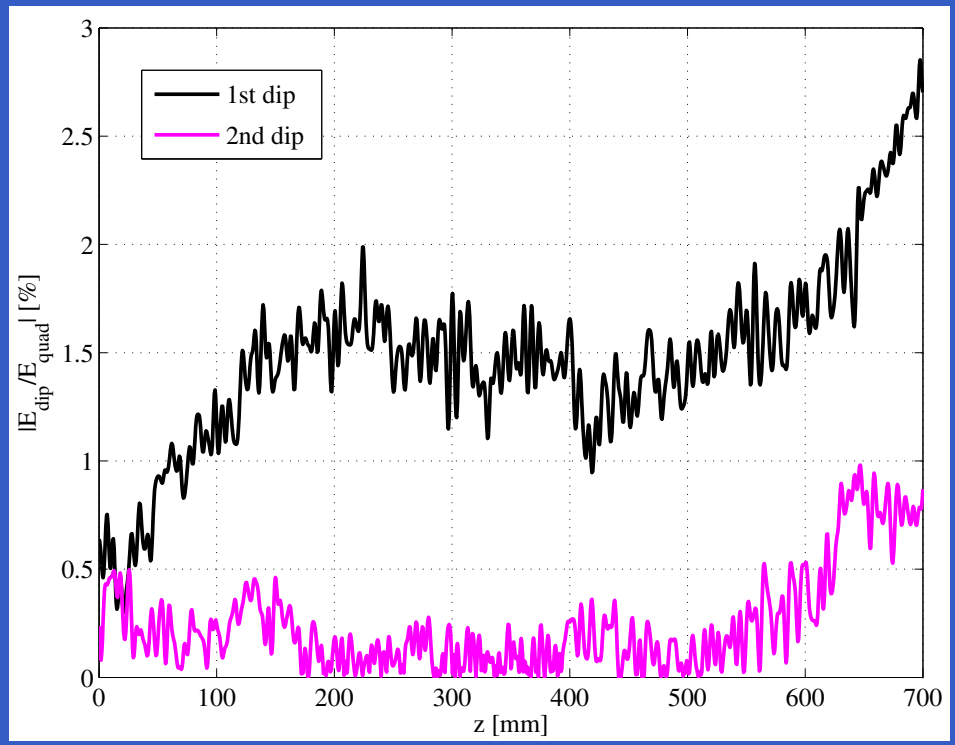
- Bead pulling allows to know electric field distribution
- four sectors $\Rightarrow$ four modes (monopole, two dipoles and a quadrupole)

Bead pulling (hot model)



- Bead pulling allows to know electric field distribution
- four sectors $\Rightarrow$ four modes (monopole, two dipoles and a quadrupole)

Bead pulling (hot model)



- Bead pulling allows to know electric field distribution
- four sectors $\Rightarrow$ four modes (monopole, two dipoles and a quadrupole)
- 3% dipole

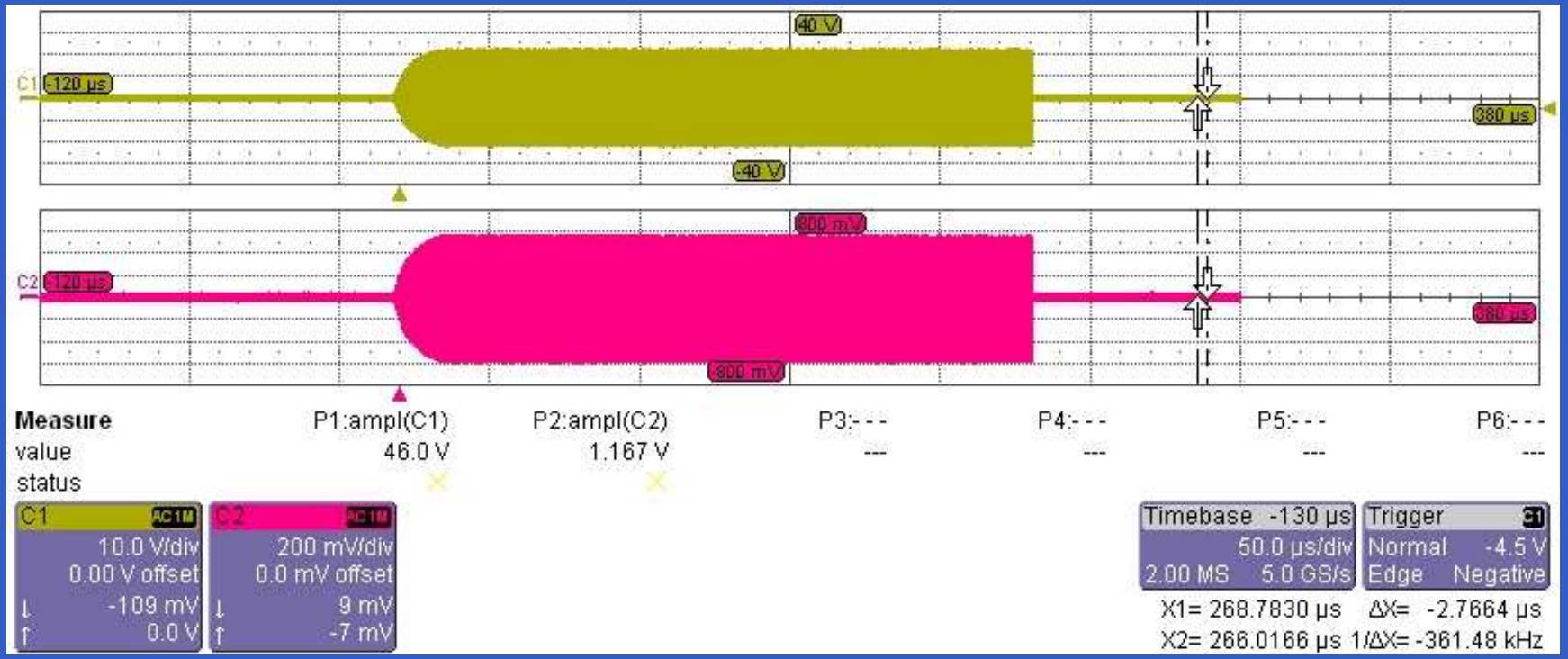
RF power source

- *Frank James* amplifier from CERN (M. Vretenar)
- Pulsed 50 kW (2 Hz max, 1 msec), f0=202.56MHz
- 3 racks (amplifier, high voltage, low level)

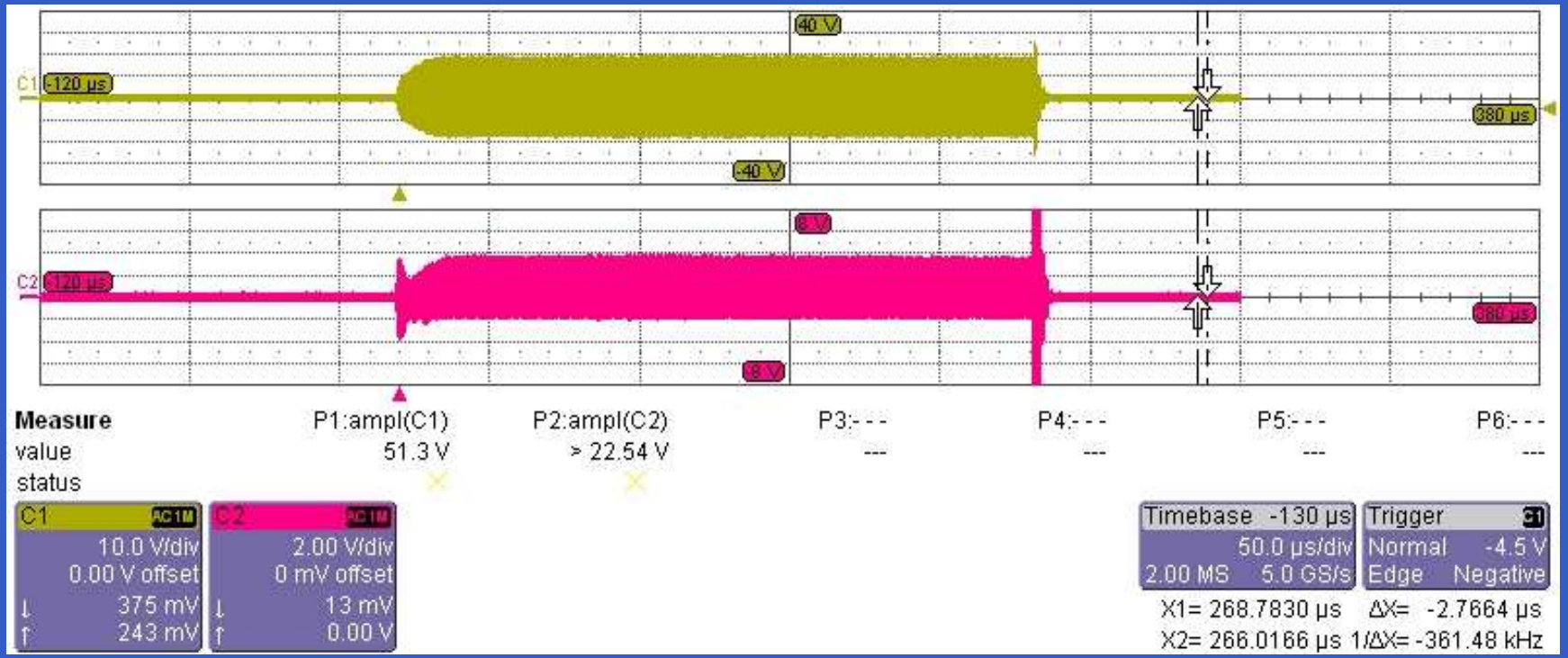
RF power source

- *Frank James* amplifier from CERN (M. Vretenar)
- Pulsed 50 kW (2 Hz max, 1 msec), f0=202.56MHz
- Home-made trigger

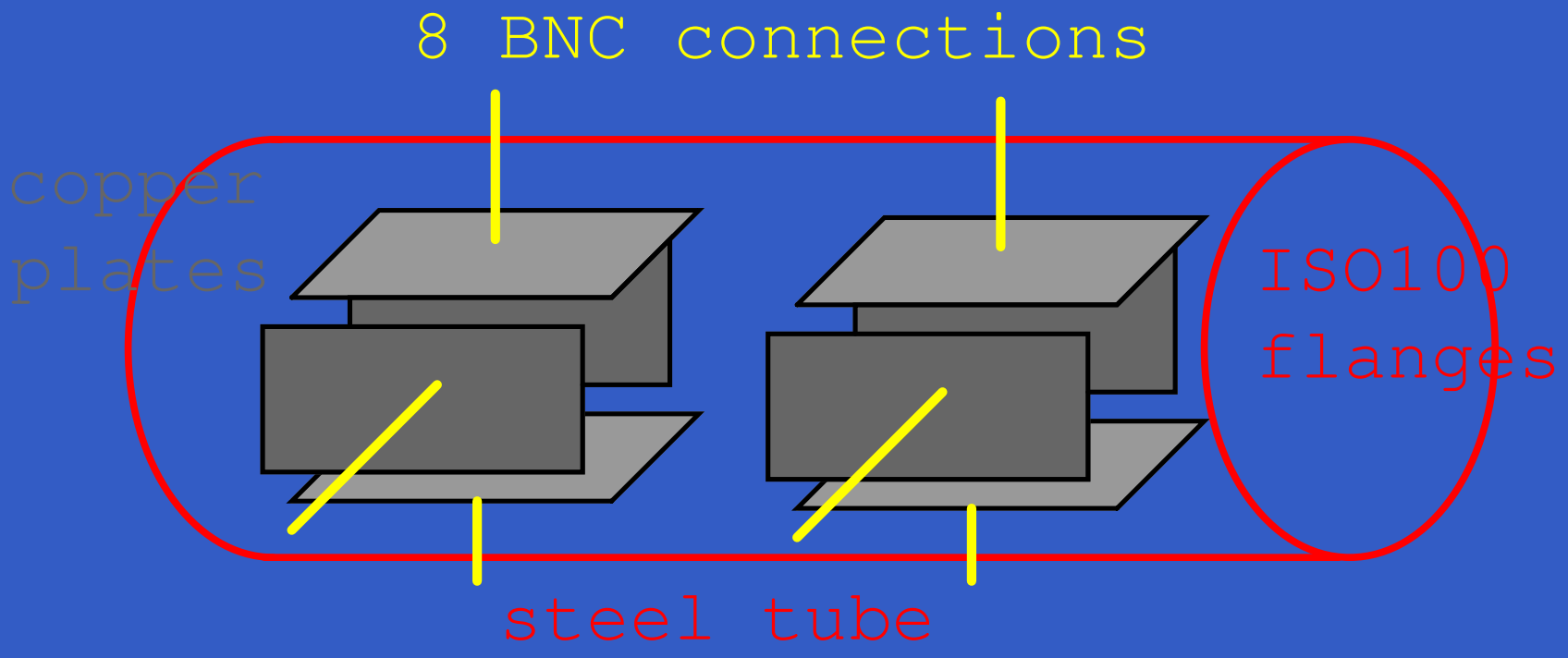
RF power tests (dummy load)



RF power tests (linear module)



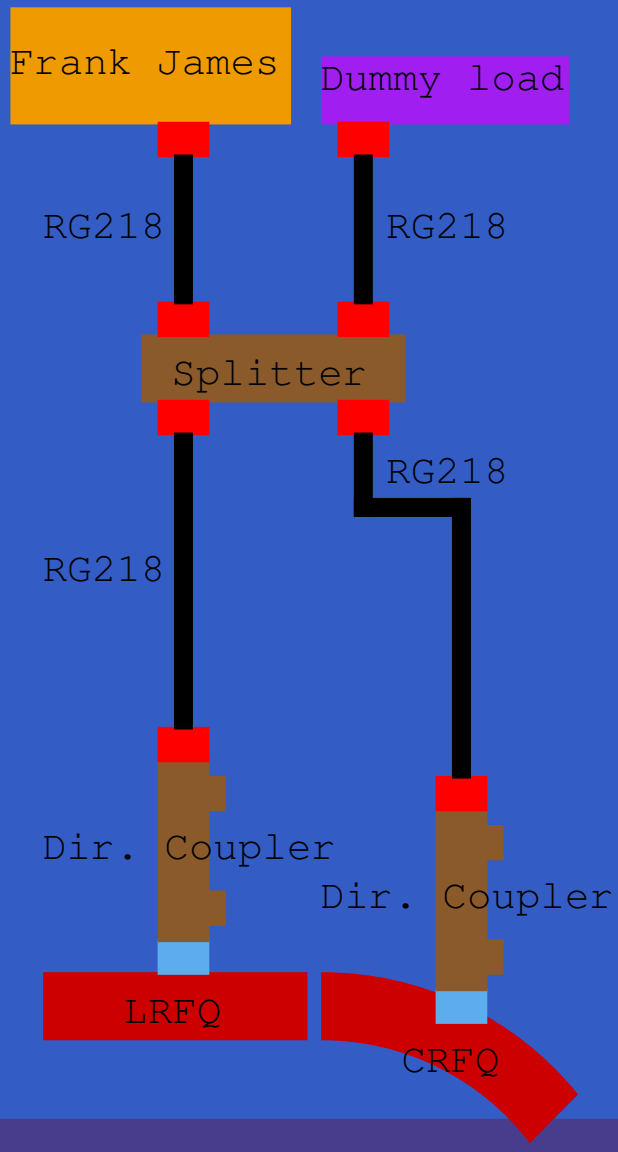
Diagnostic box design



RF diagram

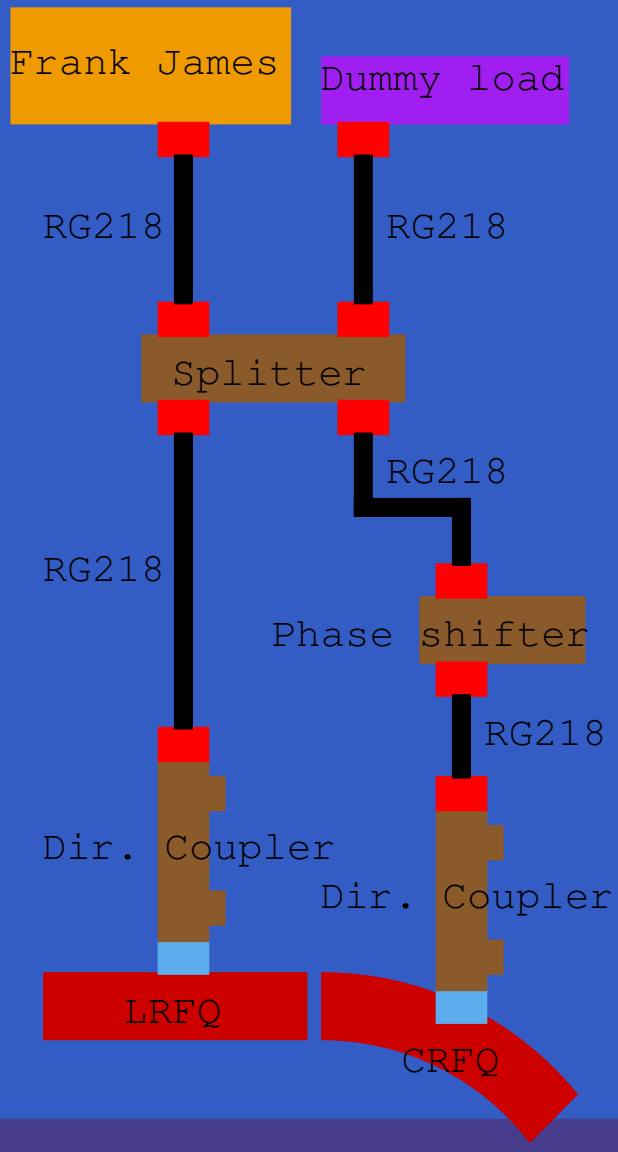
- one splitter, two directional couplers (loan from BNL)

RF diagram



- one splitter, two directional couplers (loan from BNL)

RF diagram

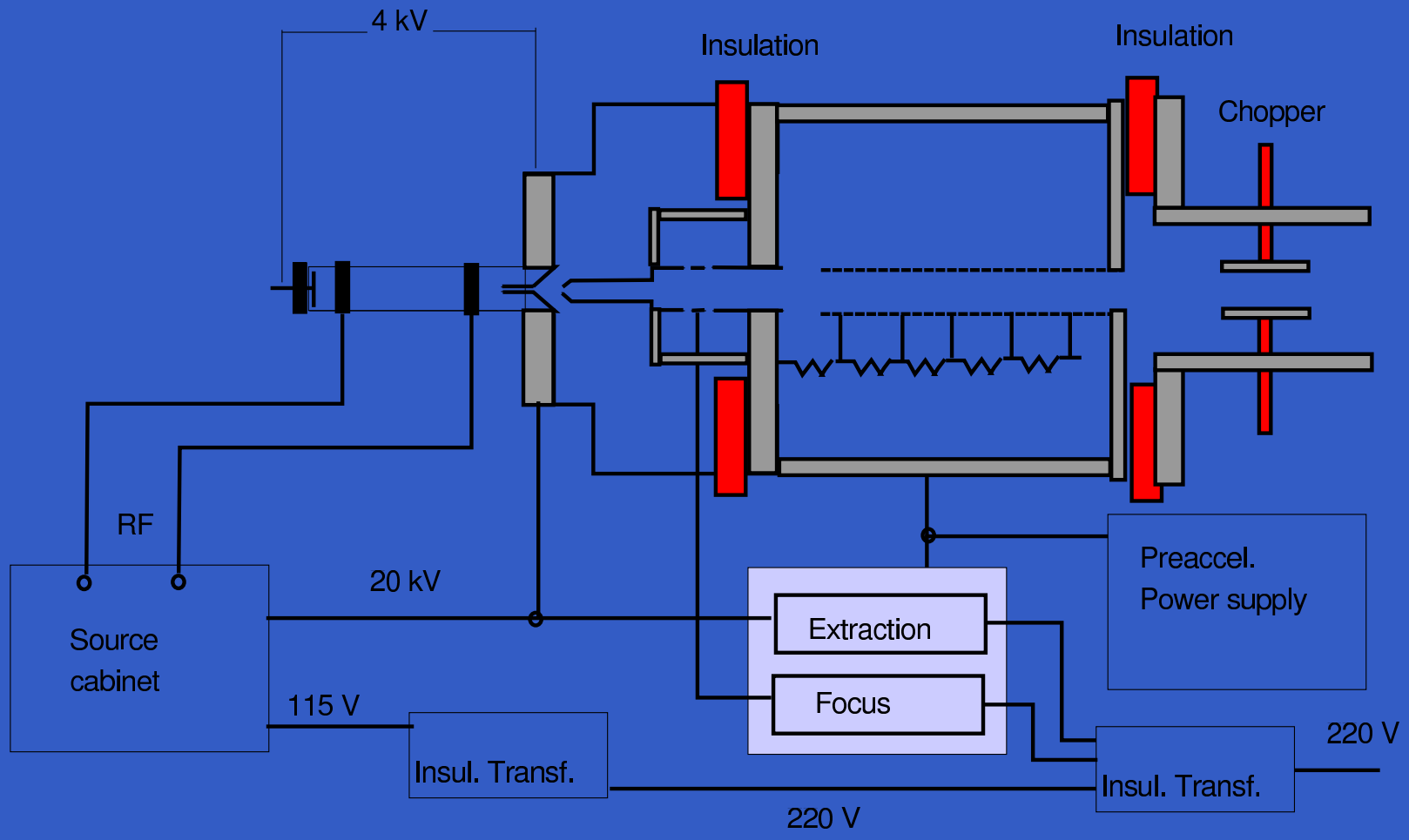


- one splitter, two directional couplers (loan from BNL)
- A phase shifter will be needed

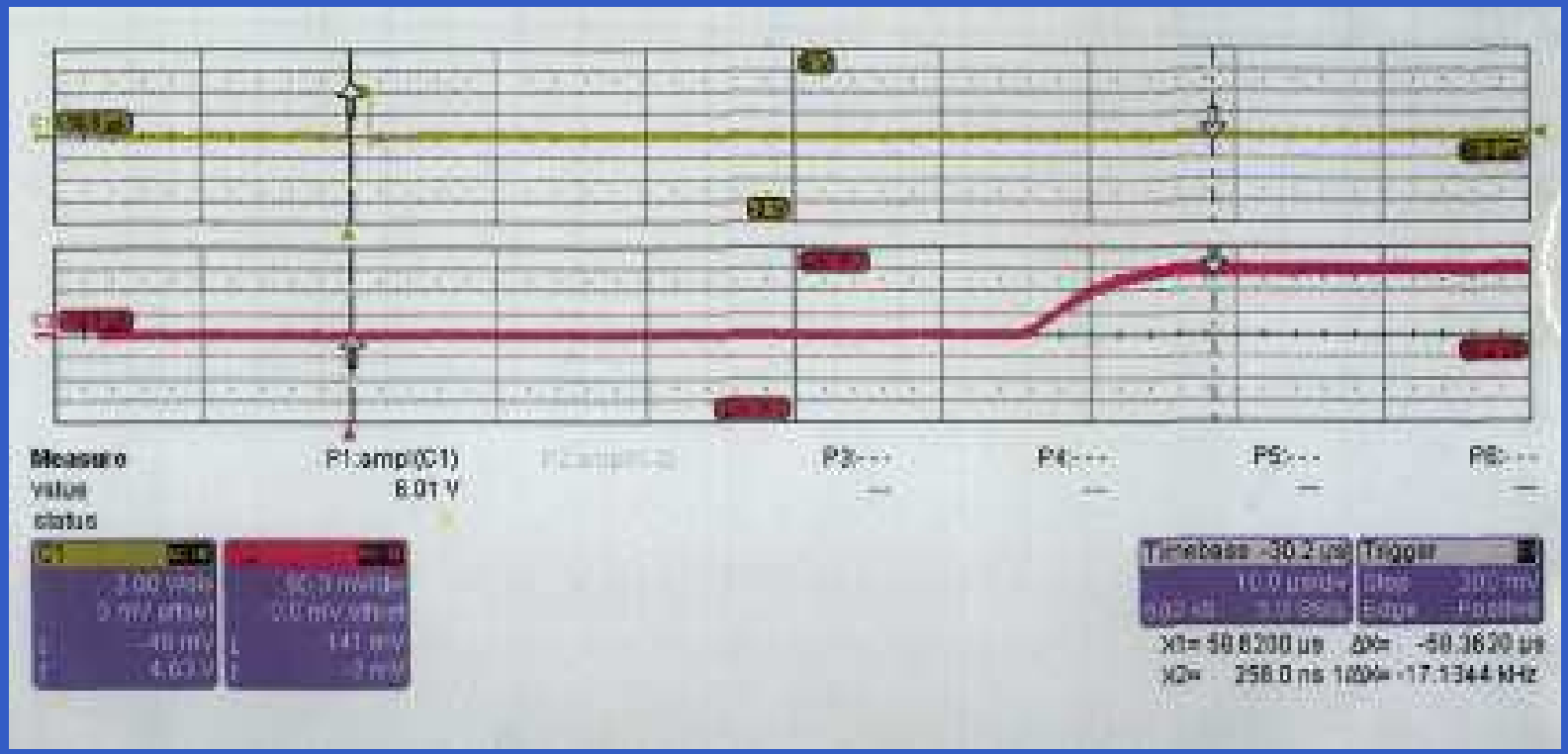
Status of the Proton Source

- 30keV, 1mA beam available
- Pre-acceleration stage added.
- Beam emittance is within specifications (5mm*mrad with 0.2mA after collimation),
- Max current is 10mA (no collimation),
- Upgrade of High Voltage DC power supplies done,
- Home-made electronic beam pulser. . .

Proton source diagram



Trigger timing



References

- A. Ruggiero, BNL-AP-65 note, 2001
- CRFQ02 workshop final relation, Benevento, Italy, October 2002
- L. Campajola, D. Davino, M.R. Masullo, A.G. Ruggiero, V.G. Vaccaro, RF excitation of linear and curved sections of the CRFQ project, EPAC2004 Conference (MOPLT055), Luzern.
- L. Campajola, D. Davino, M.R. Masullo, A.G. Ruggiero, V.G. Vaccaro, A practical demonstration of the CRFQ Storage Ring, EPAC2004 Conference (MOPLT071), Luzern.
- see next contributed oral paper to the EPAC2006 conference, Edimburgh

References thank you!

- A. Ruggiero, BNL-AP-65 note, 2001
- CRFQ02 workshop final relation, Benevento, Italy, October 2002
- L. Campajola, D. Davino, M.R. Masullo, A.G. Ruggiero, V.G. Vaccaro, RF excitation of linear and curved sections of the CRFQ project, EPAC2004 Conference (MOPLT055), Luzern.
- L. Campajola, D. Davino, M.R. Masullo, A.G. Ruggiero, V.G. Vaccaro, A practical demonstration of the CRFQ Storage Ring, EPAC2004 Conference (MOPLT071), Luzern.
- see next contributed oral paper to the EPAC2006 conference, Edimburgh